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EARLY DETECTION OF COW HOOF DISEASE USING IOT AND MACHINE LEARNING TECHNIQUES

Dr. S. VasanthKumar Assistant Professor in Computer Science Hindusthan College of Science and Commerce, Ingur,Erode-638052 Email:Vkerode89@gmail.com
Dr. K. M. Padmapriya Assistant Professor in Computer Science Hindusthan College of Science and Commerce, Ingur,Erode-638052 Email:padmapriya.kmp@gmail.com

Abstract-
Monitoring the health of dairy cattle is essential for enhancing the global dairy product supply. Farmers are increasingly disenchanted with the dairy sector due to various health challenges faced by their animals the unpredictability of severe illnesses, and rising breeding expenses. The idea of "Smart Dairy Farming" is becoming a reality, as advancements in fields like machine learning techniques and IoT are being effectively integrated into this industry. The hoof is a crucial component of an animal's anatomy and early identification of hoof injuries is vital. Timely diagnosis of lameness presents a significant challenge for farmers, as it can stem from various foot and limb disorders linked to different illnesses, management practices, or environmental conditions. The importance of preventing, detecting, and treating lameness in dairy cows is paramount, given its numerous adverse effects. Early illness detection enables farmers to implement preventive measures sooner, potentially reducing antibiotic usage, boosting milk production, and lowering veterinary costs. This insight indicates that classification algorithms may effectively differentiate between cow behaviors. The proposed cow hoof monitoring system (CHMS) which includes an accelerometer, ESP Node 32 microprocessor, and temperature sensor, facilitates continuous monitoring of cow activity to predict hoof disease at an early stage.

Keywords:
Cow hoof monitoring, IoT, Machine Learning Techniques, Cow Behavior, Early illness detection.

I. Introduction

Lameness refers to the inability of the locomotors system to function effectively, resulting in impaired movement. This condition can arise from various issues, including pain, deformities, or diseases affecting joints, bones, soft tissues, nerves, metabolic processes, or infections. In draught animals, lameness can lead to significant financial losses, as it hampers their ability to perform their intended tasks. Often, the responsibility for lameness falls on the owners of draught animals, which may stem from insufficient knowledge or greed. Enhancing surgical interventions and implementing preventive measures can help minimize financial losses for these owners.

The 2004 OIE Global Conference on Animal Welfare highlighted that animal welfare has emerged as a critical global objective in recent years. Researchers worldwide are actively investigating ways to enhance animal well-being throughout various production stages, including breeding, transportation, and slaughter [1]. These studies also aim to develop and evaluate automated systems that monitor animal welfare during breeding. Understanding the perspectives of farm managers and consumers regarding the welfare and behavior of dairy cattle can lead to the creation of relevant management indicators [2].Animal behavior serves as a clear indicator of an animal's physiological and physical condition. For cows, key activities include eating, ruminating, lying down, and walking, which farmers must regularly monitor to ensure proper care. While operators can observe cow behavior through visual inspection, this approach can be labor-intensive and time- consuming, particularly on larger farms. In the realm of precision livestock farming (PLF), innovative ICT-based solutions are being developed and tested to enhance cow monitoring and management [3]. These devices are capable of gathering extensive data, which, when processed using advanced algorithms, could significantly improve management practices.

In recent years, there has been a notable increase in solutions that integrate artificial intelligence techniques with Internet of Things (IoT) platforms. Advanced AI has emerged as a valuable resource

for analyzing the vast amounts of data generated by sensors, providing insights that would otherwise remain inaccessible. In the context of cattle farming, there are stringent regulations governing the care of livestock. Currently available methods for monitoring animal health are often labor-intensive, time-consuming, and costly [4]. Despite a high ratio of stockpersons to animals in many commercial operations, livestock producers frequently depend on manual observations to identify health and welfare issues among their herds.

Wearable sensors are becoming increasingly vital for monitoring the health and activity levels of cattle. Blinking these sensors to the IoT and observing cow behavior, new insights into their health and well-being can be gained [5, 6]. Understanding the duration of various behaviors exhibited by an animal can provide valuable information regarding its health status. However, monitoring grazing animal presents challenges, as the expansive grazing areas and the animals' natural behaviors complicate oversight. Additionally, with fewer personnel available for observation, it becomes difficult to detect unusual behaviors and ascertain their causes, complicating the task of monitoring animal welfare.

Many animals lack the ability to convey any health issues to humans. In response to this challenge, Healthcare Monitoring Systems (HMS) has developed a wireless sensor specifically for wildlife, informed by the findings of this research. If the sensor identifies any health concerns in animals, notifications will be sent to the office of a forest official and relevant veterinarians. This information can then be utilized to gain insights into the animal's condition or to administer necessary medical treatment. The proposed Wireless Sensor Network (WSN) serves as an effective approach for establishing multi-functional WSN gateways in decentralized areas, enabling efficient and cost-effective services across various applications, including monitoring systems, agricultural production, environmental management, and military operations.

The WSN incorporates sensors for temperature, smoke, pulse, respiration, heart rate, and electrocardiogram (ECG) readings. The potential for monitoring across diverse contexts is significant. The wireless device is capable of interacting with various networking sensors due to its rechargeable batteries. This study primarily focuses on measuring and observing the behavior and well-being of animals. Several elements are being examined in this research. For example, studies involving wildlife may include the installation of sensors and cameras throughout their habitat instead of directly on the animals.

A Wireless Sensor Network (WSN) consists of multiple sensors capable of gathering data, analyzing it, and communicating wirelessly with each other. Health is not onlya fundamental aspect of our existence but also plays a significant role in the over all efficiency of our bodily functions. Any disruption in this system can impact individuals' behavior and their capacity to perform daily tasks. There are numerous factors contributing to a decline in fitness levels. This article discusses various health issues affecting animals, including illnesses such as sickness, stiffness, estrus, mammary tumors, ovarian tumors, displacement an trump, ketosis, prolonged placental retention, diarrhea in heifers, and other ailments. WSN-based monitoring systems for animals collect vital data from sensors attached to the animals, measuring parameters like heart rate, respiratory rate, and pulse rate. Additionally, environmental sensors provide information on factors such as water pollution levels, rates of soil-borne diseases, airborne dust concentrations, and relative humidity (Wang Y., Wang Q., Jin S.,Long W., and Hu L., 2022).

The Wearable Sensing Animal Healthcare Monitoring System necessitates installation on a web-connected emulator device or a personal computer. This system is designed as wireless Sensor Network (WSN)-based platform for animal care management (ACM). It is purpose-driven, leaves a minimal environmental footprint, and is sustainable. The ACM is employed to oversee the overall health of animals. An array of sensors within the Animal Health Monitor (AHM) captures the physical The Animal Condition Monitor (ACM) leverages this sensor data to swiftly assess the health status of the animals through calculations based on the collected information. This process supports the health of wildlife and facilitates the early detection of potential illnesses. Data transmission will utilize Smart Health Monitors (SHMs), with IoT devices playing a pivotal role in advancing the industry (Jiang et al., 2022).

The frequency of health assessments for animals is vital in evaluating their vulnerability to natural disasters such as floods and fires. Consequently, tracking an animal's ability to navigate is made easier

with this model. Due to their limited vision, animals often find it challenging to accurately gauge distances. Therefore, it is essential to protect them by creating noise and exhibiting group behavior, similar to their natural instincts.

II. Related Work

Lameness represents a significant health issue within the cattle industry, adversely affecting both the welfare of the animals and the economic viability of operations. When cattle experience pain related to their mobility, they often alter their gait and posture to alleviate discomfort. According to Sprecher D., Hostetler D., and Kaneene J.,[7] lameness restricts cattle movement, resulting in decreased milk production, reduced fertility, and an increased culling rate. Consequently, it ranks as the third most costly health concern in the dairy sector, following reproductive issues and mastitis[8]. The implications of lameness extend beyond animal health, impacting productivity and profitability. Given its prevalence on farms, lameness is recognized as a critical health and financial challenge in contemporary cattle farming. This underscores the necessity for prompt and accurate identification of lameness causes. However, the incidence and underlying factors of lameness are influenced by farm management practices, including pasture conditions and housing systems.

Diagnosing lameness in cattle manually involves observing behavioral changes exhibited by affected animals during movement. Indicators include are diction in speed, alterations in gait, back arching, and head lowering. As the size of a farmer's herd increases, the time available for conducting manual lameness assessments typically decreases, given the extensive labor involved in cattle management.

Numerous studies have been conducted focusing on the health and behavior of cattle, with findings documented in various reports. These studies provide valuable insights into the health and welfare of cows, including their grazing duration, which is crucial for farmers to assess the adequacy of their feed. This assessment directly influences both the productivity and well-being of the cattle [9]. The literature also highlights various health monitoring systems designed for cattle, which are instrumental in identifying a broad spectrum of health- related issues. These systems facilitate the detection of potential problems by monitoring parameters such as rumination, body temperature, humidity, heart rate, and environmental temperature. Furthermore, these monitoring devices can operate remotely, utilizing wireless nodes to send alerts regarding any significant deviations, such as critical changes in body temperature or early indicators of illness.

Identifying the cause of lameness in cattle promptly is crucial for effective treatment that is both economical and preventive against future health issues. Lameness poses a significant challenge to cattle productivity and adversely affects numerous farms. Additionally, the behavior of cattle serves as a vital indicator of their overall health and well-being, which in turn influences the quantity and quality of dairy and meat products. Traditional methods for diagnosing lameness and assessing equine behavior are often time-consuming and labor- intensive, creating substantial challenges for agricultural operations. This section will explore advanced perception and analytical technologies aimed at two primary objectives: 1) diagnosing lameness and 2) evaluating and interpreting cattle behavior. We will examine the potential and obstacles of future research in these areas, as well as opportunities for advancement. Furthermore, we will review and analyze existing studies related to these topics. With the implementation of Wireless Sensor Networks (WSNs), it is now feasible to monitor cattle presence in pastures and the duration of their stay. Ensuring a high-quality indoor environment is essential for the health and welfare of cattle, as it directly impacts both the quantity and quality of their output. Proper ventilation in barns is critical to mitigate the risks associated with prolonged exposure to ammonia, which can lead to increased stress, deteriorating health, and reduced productivity. Huircan et al[7]. Developed a tracking system for cattle utilizing Zigbee technology and a localization strategy within WSNs.

Ecologists must understand how animals respond to environmental changes. Advanced networked sensor technologies offer precise measurements of both the environment and animal behavior, enabling effective tracking, study, and conservation of wildlife. This article examines traditional animal tracking methods, the functionality of the Internet of Things(IoT) in animal ecology, and the advantages and disadvantages associated with its use. It also discusses the theoretical limitations of IoT within this field. Although IoT represents a novel approach to studying animal ecology, further

research is essential to establish a robust theoretical framework and to integrate it into appropriate scientific methodologies.

In 2017, Asuka Noda, born in Japan, highlighted the need for increased support for those managing grazing animals in vineyards. To facilitate this, it is crucial to monitor and train animals regarding their locations and feeding behaviors. Such a system would allow sheep to graze safely in areas like orchards and vineyards. This suggests the implementation of an IoT-based system for tracking animal behavior, utilizing a local IoT network and a cloud platform capable of processing and storing data. This system would gather information from animals and automate the movement of sheep through vineyard areas. The cloud platform incorporates machine learning capabilities, enabling the extraction of valuable insights from the data collected within the IoT network. Additionally, the article presents outcomes related to the machine learning platform, particularly its application in identifying and diagnosing posture-related disorders in animals, with promising preliminary results[10]. A review of the various tested algorithms is also included, as multiple algorithms were evaluated.

Animal monitoring has been the subject of numerous publications, each with distinct objectives. For instance, some research has focused on the migratory patterns of wildlife [J. Hunter, 2013], while others have analyzed the behavior of grazing animals [L. A. Gonzalez,
G. J. Bishop-Hurley, R. N. Handcock, and C. Crossman, 2015; M. L. Williams, N. Mac Parthaliin, P. Brewer, W. P. J. James, and M. Rose, 2016; R. Dutta, 2014]. Studies have also examined grazing site characteristics, animal posture, and estrus behavior [18]. Although few researchers engage in real-time analysis, the majority utilize sensors to capture animal behavior for subsequent examination. Williams et al. employed machine learning methods to analyze GPS data from forty cows over a four-month period to understand their grazing habits. They utilized the WEKA data mining suite and implemented four different machine learning algorithms, successfully distinguishing between walking, resting, and grazing behaviors. However, the reliance on a single sensor for tracking poses challenges to data accuracy, particularly during eating or sleeping. Despite issues related to high energy consumption from GPS devices, the findings indicate that the animal monitoring system is effective for various applications in tracking animal activity and anticipating health issues [11].

Estrus detection represents a significant area of focus in animal monitoring. This interest likely stems from the potential benefits of effective insemination management for business operations. In the studies referenced, accelerometer sensors were commonly affixed to the legs or necks of cows to track their activity levels. The collected data is subsequently analyzed to identify activity peaks indicative of estrus. Beyond academic research, there are also commercial devices that transmit monitoring data via wireless networks. These systems facilitate remote observation of eating, ruminating, and activity levels, thereby simplifying cow management. In the research conducted by Dutta and his team, monitoring collars were utilized to assess the cows' tri-axial acceleration and magnetic field. Machine learning algorithms were employed to evaluate individual classifiers, such as "Binary Tree" and "Naive-Bayes," or combinations of these classifiers to establish thresholds for distinguishing various activities. These thresholds are then applied to categorize the activities accordingly.

Even simpler classifiers, like the "Binary Tree," demonstrate over 90% accuracy and sensitivity for certain categorized activities.

RFID and WSN technologies play a crucial role in the cattle industry by enabling the monitoring of individual animal characteristics and their habitats. These technologies are also instrumental in tracking the breeding history of livestock. Additionally, RFID-based wireless sensor networks (WSNs) have been implemented to monitor animal health. Researchers have leveraged wireless RFID technology to automatically assess the physiological and behavioral patterns of animals, which aids in health monitoring. Body temperature serves as a significant indicator of ananimal's overall lwell-being, providing insights into stress levels, the impact of shearing, and the early detection of diseases and disorders. According to Arfuso, Rizzo, and Giannetto (2016), rectal temperature variations correlate with an animal's age. In contemporary practices, animal health management systems have evolved significantly. Most of these systems primarily focus on health monitoring and alerting farmers through SMS notifications or IoT platforms like Thing Speak. Such advancements underscore the importance of early disease detection and the continuous collection of health data to ensure the well-being of livestock.

III. Cow Hoof Diseases

A. Limping or lameness is a common clinical sign associated with bovine hoof disorders. This condition may arise from physical injuries, such as cuts or punctures, or from microbial infections like foot rot or digital dermatitis. When a cow shows signs of lameness, it is essential to examine the affected hoof and, if necessary, consult a veterinarian for further assessment.

B. Swelling or inflammation around the hoof can signal an infection, injury, or other underlying health issues. The affected area may also feel warm or painful to the touch. Common causes of hoof swelling in cattle include foot rot, abscesses, and injuries. In some cases, swelling may indicate a more serious condition, such as laminitis.

C. An abnormal hoof shape is a concern in cattle, as hooves should typically be uniform and symmetrical. The presence of irregular or uneven hooves may point to underlying problems. Such deformities can result from various factors, including genetic issues, poor nutrition, and physical injuries. Without appropriate medical care, these conditions can lead to reduced mobility and additional complications.

D. Cracks or fissures in the hooves may suggest dryness or injury, requiring interventions like trimming or treatment to prevent further issues. Several factors can contribute to the development of cracks, including excessive moisture, physical trauma, or a lack of essential nutrients. In some cases, these cracks may indicate a more serious condition, such as laminitis.

E. Lesions orulcers on the hooves maysignalan infection or other underlying health issues, warranting veterinary attention. The causes of these conditions can vary widely, including bacterialorfungalinfections,physicaltrauma,ornutritionaldeficiencies.Without appropriate medical care, the presence of such lesions and ulcers can lead to lameness and a range of other complications.

F. Rapid or uneven wear of a cow's hooves may indicate an underlying problem with the animal's gait or hoof structure. Several factors can contribute to this excessive wear,including poor hoof maintenance, nutritional deficiencies, and physical injuries. If left unaddressed, this issue may lead to lameness and other related problems.

G. A foul odor coming from the hooves may suggest an infection or other health issues, requiring the attention of a veterinary professional. This condition may also be accompanied by additional symptoms such as swelling, fever, or discharge. The unpleasant smell in cows can result from various causes, including bacterial or fungal infections, foot rot, and digital dermatitis. Without timely medical intervention, these conditions can impair mobility and lead to further complications.

IV. Proposed System

This research primarily aimed to analyze various methods for deploying accelerometer sensors, focusing specifically on the use of neck tags for cows. The device is affixed to the cow's neck, ensuring that it does not interfere with the animal's normal activities. Additionally, three alternative deployment locations were evaluated: the front leg, the collar, and the ear. This section outlines the procedures used to attach the X16-mini and AX3devices at each site, as wellas the orientation ofthe sensor axes. The axis orientations for all deployment points were consistent and maintained as a constant throughout the trials. While the orientation of each axis does not influence the sensor measurements, understanding this aspect is crucial for accurate data interpretation. The orientations of the X, Y, and Z axes are illustrated in Fig. 1, depicting dorso-ventral, lateral, and anterior-posterior alignments.

The four sensors are integrated into a device known as the Cow Hoof Health Monitoring System (CHMS). This device is linked to Things board through an internet connection. Mounted on the cow's neck collar, the CHMS device efficiently gathers data related to the cow's movement and health, subsequently transmitting this information to Things board via Wi-Fi. As a result, all data concerning the cow is readily accessible on the Things board platform, enabling straightforward monitoring of the cow's movement and health status.

The Arduino code for monitoring the health of a cow's hoof facilitates the connection of the Node to Things Board. Following successful compilation, the code has been uploaded to the device, which is now connected via Wi-Fi. This enables the user to monitor real-time data regarding the cow's position,

health, and temperature.

V. Results and Discussion

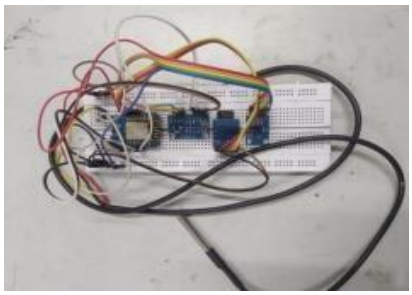

Figure 1a. CHMS device prior to the process.

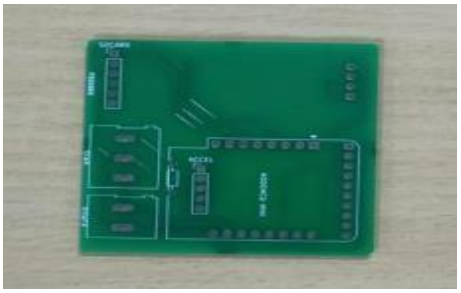

Figure1b. Circuit board of CHMS. soldering

The preceding Fig. 1a illustrates that prior to the assembly of the CHMS device, all sensors were connected to the breadboard for testing purposes. Additionally, Fig. 1b demonstrates that the components depicted were integrated onto the PCB board following the successful testing of the device.

Fig2.Circuit of CHMS

Figure 2 illustrate that all necessary sensors are integrated beneath the PCB board. Additionally, the entire CHMS Device has been enclosed within the box.

Fig 3.Cow Hoof Health Checking

Figure 3 illustrates the researcher examining the health status of the cow's hoof with the CHMS Device.

Fig4.Cowbody temperature from CHMS Device

The above picture Fig.4. Shows the cow body temperature displayed on Things board dashboard. The CHMS Device captures the data with its real time; that is, the same time which is displayed on the device monitor while collecting the data from the hoof will be displayed when it is uploaded on Things board.

Conclusion

Monitoring the health of cows presents significant challenges in today's agricultural landscape; however, the CHMS Device simplifies this task considerably. As the number of dairy farms continues to rise, integrating advanced systems has become essential for modern farming practices. In the current environment, it is increasingly advantageous to streamline efforts and achieve results in a shorter timeframe. Tasks that traditionally required hours of manual labor can now be efficiently handled by advanced technology, exemplified by the CHMS Device, which allows for precise health monitoring with minimal effort by simply attaching the device to the cow's collar. This paper has illustrated, through detailed figures, how the entire monitoring process can be executed effectively and professionally, with data seamlessly transmitted to Things board via Wi-Fi connectivity.

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